N-shell Photoionization of Kr^+

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INTRODUCTION

Homologous sequences of elements (those contained in columns of the periodic table) exhibit comparable physical and chemical properties owing to similarities in valence electronic structure. Until recently, the study of homologous sequences has been limited to neutral atoms. The ion-photon beamline (IPB) located on ALS beamline 10.0.1.2 is now being used to investigate homologous sequences of positive ions. Ionic targets add another dimension to these studies since measurements can also be made along isoelectronic sequences of atoms. The preliminary Kr^+ photoionization measurements presented here are complementary to previous measurements of open-shell Halide-like ions such as Ne^+ [1]and Ar^+ [2]. For each of these ions, a detailed theoretical description of the photoionizaton process is difficult to construct. Heavier ions such as Kr^+ present the most imposing challenge for theory because atomic complexity increases with electron number. Moreover, with increasing atomic number, relativistic interactions become more important, and the representation of angular momenta of various states of the ion may need to incorporate both LS- and JJ-coupling schemes in order to accurately predict both the ionic structure and photon-ion collision properties.

EXPERIMENT

Kr^+ beams were produced in the Cuernavaca Ion Gun Appartus (CIGA). More detailed accounts of the ion source and IPB experimental apparatus are given elsewhere [1,2,3], but a brief overview of operating parameters for Kr^+measurements follows. Krypton-ions were accelerated to a kinetic energy of 6 keV, and merged with a photon beam from ALS. Typically, the ion beam current delivered to the interaction region was ~50nA. The photoion signal rate was ~2kHz for the direct (non-resonant) photoionization process. The signal-to-noise ratio approached 20:1. During all measurements, the average base pressure in the interaction region was maintained at 6×10^{-10} Torr. A 2kV bias was placed on the interaction region in order to energy label the product Kr^{+2} ions. All measurements were made using the ALS Undulator Beamline 10.0.1 low-energy spherical-grating monochromator (380 lines/mm) with the entrance and exit slits set for a photon energy resolution of ~10meV. The higher-order component in the photon beam was determined to be 3%. The energy step size was 1meV between data points. For photon energies below 29eV, the dwell time at each data point was 2 seconds. Above 29eV, the dwell time was increased to 4 sec per point in order to obtain uniform counting statistics. This was necessary to compensate for the decrease in the cross section at higher photon energies.

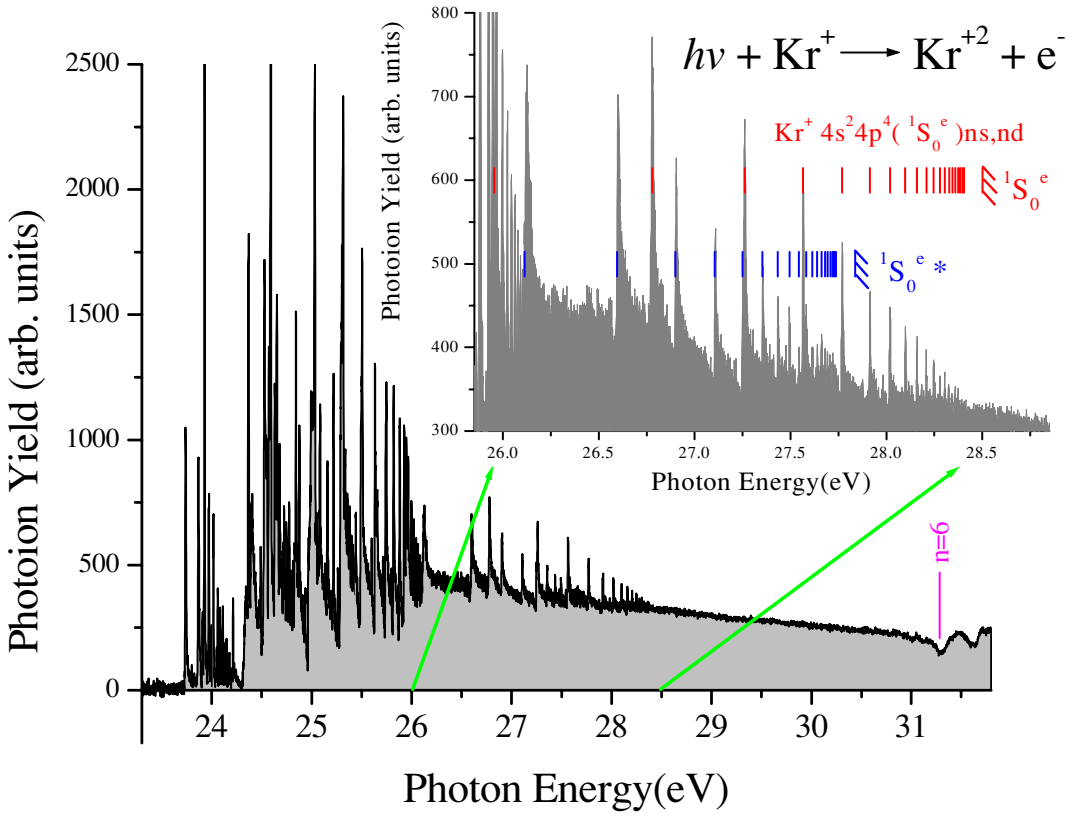

Figure 1

RESULTS

Shown above in Figure 1 are the preliminary results of a photoion yield spectrum for the photoionization of Kr^+ (Br-like) from below the $4s^24p^5$ ($^2P_{1/2}^{\,o}$)→$4s^24p^4$($^3P_2^{\,e}$) threshold (23.694eV) to ~32eV. The window resonance at 31.25eV corresponds to the n=6 term of the $4s4p^5$ ($^3P_2^{\,o}$)np Rydberg series that has a series limit at 38.734eV. The spectrum took approximately 12hrs to accumulate. Also visible in the spectrum are resonances of the $4s^24p^4$($^1D_2^{\,e}$)ns,nd Rydberg series converging to a series limit of 26.176eV. The inset in the figure is an enlargement of resonances converging to the $4s^24p^4$ ($^1S_0^{\,e}$) Rydberg series limit. The two series limits shown correspond to photoionization out of the $^2P_{1/2}$(*) and $^2P_{3/2}$ target ion states. A survey of the data for Kr^+, Ne^+ and Ar^+ indicates that the general photoionization features are similar for each of these noble gas ions. In contrast, a more detailed analysis indicates that the Fano line profiles are unique for each of the ions, indicating that the LS-coupling approximation is probably insufficient to describe finer photoionization details. Calculations for the photoionization of Kr^+ are currently underway in an attempt to resolve many of these issues[4]. An isoelectronic comparison can be made using the results of previous measurements for the photoionization of atomic Br[5]. These indicate the both Kr^+ and Br have similar photoionization properties. Future measurements on singly-charged noble gas ions will determine the total absolute M-shell photoionization cross

section for Kr^+ and will investigate the O-shell photoionization of Xe^+. Finally, a new, state-of-the-art Electron Cyclotron Resonance (ECR) ion source is currently under development which will allow for extended isoeletronic studies of ions such as K^{2+} and Sr^{3+}.

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